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HEAT SOURCE AND MASS TRANSFER EFFECTS ON MHD FLOW OF AN ELASTO-VISCOUS FLUID THROUGH A POROUS MEDIUM

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ABSTRACT: An analytical study is performed to examine the effects of temperature dependent heat source on the unsteady free convection and mass transfer flow of an elasto-viscous fluid past an exponentially accelerated infinite vertical plate in the presence of magnetic field through porous medium. The plate temperature is raised linearly with time t and the concentration level near the plate is raised to C'_w. The Laplace transform method is used to obtain the expression for velocity. The effect of various parameters, occurring into the problem, on velocity field is discussed with the help of graphs.
KEYWORDS: MHD, Free convection, Mass diffusion, Visco-elastic fluid, Porous medium, heat source

❖ INTRODUCTION

The problem of free-convection and mass transfer flow of an electrically-conducting fluid past an infinite plate under the influence of a magnetic field has attracted interest in view of its application to geophysics, astrophysics, engineering, and to the boundary layer control in the field of aerodynamics. Soundalgekar (1979) has derived an exact solution for the flow past an impulsively started infinite vertical plate in its own plane when the convection current is set up due to temperature as well as concentration gradient. MHD effects on impulsively started vertical infinite plate with variable temperature in the presence of transverse magnetic field were studied by Soundalgekar et al. (1981). But in these papers the effects of temperature-dependent heat sources have not been taking into account. Such a situation exists in many industrial or technological applications, solar energy problems, or in problem of space sciences. From this point of view, Raptis and Tzivanidis (1981) have studied the effects of mass transfer, free convection currents, and heat sources on the Stoke's problem for an infinite vertical plate. Basant kumar Jha and Ravindra Prasad (1991) have studied the effects of heat source on MHD free-convection and mass transfer flow through a porous medium. In many industrial applications, the flow past an exponentially accelerated infinite vertical plate plays an important role. This is particularly important in the design of spaceship, solar energy collectors, etc. From this point of view, free convection effects on flow past an exponentially accelerated vertical plate was studied by Singh and Naveen kumar (1984). The skin friction for accelerated vertical plate has been studied analytically by Hossain and Shayo (1986). Basant kumar Jha et al. (1991) analyzed mass transfer effects on exponentially accelerated infinite vertical plate with constant heat flux and uniform mass diffusion. Recently Muthucumaraswamy et al. (2008) studied heat transfer effects on flow past an exponentially accelerated vertical plate with variable temperature.

On the other hand, considerable interest has been developed in the study of the interaction between magnetic fields and the flow of electrically-conducting incompressible elasto-viscous fluid due to its wide applications in modern technology. The study of an elasto-viscous pulsatile flow helps to understand the mechanisms of dialysis of blood through an artificial kidney. One such model of a visco-elastic fluid has been proposed by walter (1962) for a liquid of small relaxation time. Soundalgekar (1974) studied the flow of an elasto-visous fluid (walter's liquid B^1) past an infinite plate. Singh (1983) studied the MHD flow of an elasto-visous fluid (walter's liquid B^1) past an infinite horizontal plate for both the classes of impulsively as well as uniformly accelerated motion. Again Singh (1984) studied the free-convection flow of visco-elastic fluid past an accelerated vertical plate. Samria et al. (1990) studied the laminar flow of an electrical-conducting walter's liquid B^1, past an infinite non-conducting vertical plate for impulsive as well as uniformly accelerated motion of the plate, in the presence of a transverse magnetic field. Chowdhury and Islam (2000) studied MHD free convection flow of a visco-elastic fluid past a vertical porous plate. Recently Rajesh and Varma (2010) studied the effects of thermal radiation on unsteady free convection flow of an elasto-viscous fluid over a moving vertical plate with variable temperature in the presence of magnetic field through porous medium

This paper deals with the analytical study of Heat source and mass transfer effects on MHD free convection flow of a visco-elastic fluid past an exponentially accelerated infinite vertical plate with variable temperature through porous medium. The dimensionless governing equations are solved using the Laplace transform technique.

MATHEMATICAL ANALYSIS

The unsteady free convection and mass transfer flow of an electrically conducting incompressible elasto-viscous fluid past an infinite vertical plate through porous medium in the presence of heat source has been considered. A magnetic field of uniform strength B_0 is applied transversely to the plate. The induced magnetic field is neglected as the magnetic Reynolds number of the flow is taken to be very small. The flow is assumed to be in x'-direction which is taken along the vertical plate in the upward direction .The y'-axis is taken to be normal to the plate. Initially the plate and the fluid are at the same temperature T'_∞ with concentration level C'_∞ at all points. At time $t'>0$, the plate is exponentially accelerated with a velocity $u = u_0 \exp(a't')$ in its own plane and the plate temperature is raised linearly with time t and the level of concentration near the plate is raised to C'_w. The effect of viscous dissipation is assumed to be negligible. Then by usual Boussinesq's approximation, the unsteady flow is governed by the following equations.

$$\frac{\partial u'}{\partial t'} = \nu \frac{\partial^2 u'}{\partial y'^2} + g\beta\left(T' - T'_\infty\right) + g\beta^*\left(C' - C'_\infty\right) - \frac{K_0}{\rho}\frac{\partial^3 u'}{\partial y'^2 \partial t'} - \frac{\sigma B_0^2 u'}{\rho} - \frac{\nu u'}{K'} \tag{1}$$

$$\rho C_p \frac{\partial T'}{\partial t'} = \kappa \frac{\partial^2 T'}{\partial y'^2} + Q' \tag{2}$$

$$\frac{\partial C'}{\partial t'} = D\frac{\partial^2 C'}{\partial y'^2} \tag{3}$$

With the initial and boundary conditions:

$$\begin{array}{llll} t' \le 0, \ u' = 0, & T' = T'_\infty, & C' = C'_\infty & \text{for all } \ y' \\ t' > 0, \ u' = u_0 \exp(a't'), & T' = T'_\infty + \left(T'_w - T'_\infty\right)At', & C' = C'_w & \text{at } \ y' = 0 \\ u' = 0, & T' \to T'_\infty, & C' \to C'_\infty, & \text{as } \ y' \to \infty. \end{array} \tag{4}$$

where $A = \frac{u_0^2}{\nu}$.

On introducing the following non-dimensional quantities:

$$u = \frac{u'}{u_0}, t = \frac{t'u_0^2}{\nu}, y = \frac{y'u_0}{\nu}, \theta = \frac{T' - T'_\infty}{T'_w - T'_\infty}, G_r = \frac{g\beta\nu\left(T'_w - T'_\infty\right)}{u_0^3},$$

$$C = \frac{C' - C'_\infty}{C'_w - C'_\infty}, G_m = \frac{g\beta^*\nu\left(C'_w - C'_\infty\right)}{u_0^3}, P_r = \frac{\mu C_p}{\kappa}, S_c = \frac{\nu}{D}, M = \frac{\sigma B_0^2 \nu}{\rho u_0^2},$$

$$F = \frac{Q\nu^2}{\kappa u_0^2}, S = \frac{K_0 u_0^2}{\rho \nu^2}, \ K = \frac{u_0^2 K'}{\nu^2}, \ a = \frac{a'\nu}{u_0^2} \tag{5}$$

in equations (1) to (4), leads to

$$\frac{\partial u}{\partial t} = \frac{\partial^2 u}{\partial y^2} - S\frac{\partial^3 u}{\partial y^2 \partial t} - Mu - \frac{u}{K} + G_r\theta + G_m C \tag{6}$$

$$P_r \frac{\partial \theta}{\partial t} = \frac{\partial^2 \theta}{\partial y^2} - F\theta \tag{7}$$

$$S_c \frac{\partial C}{\partial t} = \frac{\partial^2 C}{\partial y^2} \tag{8}$$

With the initial and boundary conditions:

$$\begin{array}{ll} t \le 0: \quad u = 0, \ \theta = 0, \ C = 0 & \text{for all } \ y \\ t > 0: \quad u = \exp(at), \ \theta = t, \ C = 1 & \text{at } \ y = 0 \\ u = 0, \ \theta \to 0, \ C \to 0 & \text{as } \ y \to \infty \end{array} \tag{9}$$

In the present analysis we have considered the heat generation (absorption) of the type

$$Q' = Q\left(T'_\infty - T'\right) \tag{10}$$

where $\frac{Q'}{\rho C_p}$ is the volumetric rate of heat generation (absorption). All the physical parameters are defined in the nomenclature. For solving the problem, we take, Beard and Walters (1964), u in the form

$$u = U_0 + SU_1$$

The solution of equations (6) to (8) under initial and boundary condition (9) and by use of equation (11) by the Laplace Transform technique is given by

$$C = erfc\left(\frac{y\sqrt{S_c}}{2\sqrt{t}}\right) \tag{12}$$

$$\begin{aligned}\theta = &\left(\frac{t}{2}+\frac{yP_r}{4\sqrt{F}}\right)\left[\exp\left(y\sqrt{F}\right)erfc\left(\frac{y\sqrt{P_r}}{2\sqrt{t}}+\sqrt{\frac{Ft}{P_r}}\right)\right]\\ &+\left(\frac{t}{2}-\frac{yP_r}{4\sqrt{F}}\right)\left[\exp\left(-y\sqrt{F}\right)erfc\left(\frac{y\sqrt{P_r}}{2\sqrt{t}}-\sqrt{\frac{Ft}{P_r}}\right)\right]\end{aligned} \tag{13}$$

$$\begin{aligned}u = &B_{13}+\frac{cG_r}{d}\left(B_{14}-B_{16}\right)+\frac{G_r}{d}\left(B_3+B_{10}-B_{11}-B_2\right)\\ &+\frac{G_m}{M'}\left(B_{15}+B_{17}-B_{18}-B_2\right)+\frac{cG_rS\left(F-cP_r\right)}{d\left(1-P_r\right)}\left(B_1-B_9\right)\\ &-\frac{FG_rS}{d\left(1-P_r\right)}\left(B_2-B_3\right)-\frac{SbG_mS_c}{M'\left(1-S_c\right)}\left(B_4-B_{12}\right)-\frac{yS}{2}B_5\\ &-\frac{ycSG_r}{2d}\left(B_6-B_7\right)-\frac{ySG_mb}{2M'}B_8-\frac{SG_rF}{d\left(P_r-1\right)}\left(B_{10}-B_{11}\right)\end{aligned} \tag{14}$$

where

$$\begin{aligned}B_1 = &\left[\exp\left(y\sqrt{M'-c}\right)erfc\left(\frac{y}{2\sqrt{t}}+\sqrt{\left(M'-c\right)t}\right)\right]\left(\frac{t\exp(-ct)}{2}+\frac{y\exp(-ct)}{4\sqrt{M'-c}}\right)\\ &+\left[\exp\left(-y\sqrt{M'-c}\right)erfc\left(\frac{y}{2\sqrt{t}}-\sqrt{\left(M'-c\right)t}\right)\right]\left(\frac{t\exp(-ct)}{2}-\frac{y\exp(-ct)}{4\sqrt{M'-c}}\right)\end{aligned}$$

$$B_2 = \frac{1}{2}\left[\exp\left(-y\sqrt{M'}\right)erfc\left(\frac{y}{2\sqrt{t}}-\sqrt{M't}\right)+\exp\left(y\sqrt{M'}\right)erfc\left(\frac{y}{2\sqrt{t}}+\sqrt{M't}\right)\right]$$

$$\begin{aligned}B_3 = \frac{\exp(-ct)}{2}&\left[\exp\left(-y\sqrt{M'-c}\right)erfc\left(\frac{y}{2\sqrt{t}}-\sqrt{\left(M'-c\right)t}\right)\right.\\ &\left.+\exp\left(y\sqrt{M'-c}\right)erfc\left(\frac{y}{2\sqrt{t}}+\sqrt{\left(M'-c\right)t}\right)\right]\end{aligned}$$

$$\begin{aligned}B_4 = &\left[\exp\left(-y\sqrt{b+M'}\right)erfc\left(\frac{y}{2\sqrt{t}}-\sqrt{\left(b+M'\right)t}\right)\right]\left(\frac{\exp(bt)}{2}+\frac{tb\exp(bt)}{2}-\frac{yb\exp(bt)}{4\sqrt{b+M'}}\right)\\ &+\left[\exp\left(y\sqrt{b+M'}\right)erfc\left(\frac{y}{2\sqrt{t}}+\sqrt{\left(b+M'\right)t}\right)\right]\left(\frac{\exp(bt)}{2}+\frac{tb\exp(bt)}{2}+\frac{yb\exp(bt)}{4\sqrt{b+M'}}\right)\end{aligned}$$

$$\begin{aligned}B_5 = &\left(\frac{y^2}{4t^2}-\frac{1}{2t}+a\right)\frac{\exp\left[-\left(M't+\frac{y^2}{4t}\right)\right]}{\sqrt{\pi t}}\\ &+\frac{a\exp(at)\sqrt{a+M'}}{2}\left[\exp\left(-y\sqrt{a+M'}\right)erfc\left(\frac{y}{2\sqrt{t}}-\sqrt{\left(a+M'\right)t}\right)\right.\\ &\left.-\exp\left(y\sqrt{a+M'}\right)erfc\left(\frac{y}{2\sqrt{t}}+\sqrt{\left(a+M'\right)t}\right)\right]\end{aligned}$$

$$B_6 = \frac{\exp\left[-\left(M't + \frac{y^2}{4t}\right)\right]}{\sqrt{\pi t}} + \frac{\sqrt{M'}}{2}\left[\exp\left(-y\sqrt{M'}\right)erfc\left(\frac{y}{2\sqrt{t}} - \sqrt{M't}\right) - \exp\left(y\sqrt{M'}\right)erfc\left(\frac{y}{2\sqrt{t}} + \sqrt{M't}\right)\right]$$

$$B_7 = \frac{\exp\left[-\left(M't + \frac{y^2}{4t}\right)\right]}{\sqrt{\pi t}} + \frac{\exp(-ct)\sqrt{M'-c}}{2}\left[\exp\left(-y\sqrt{M'-c}\right)erfc\left(\frac{y}{2\sqrt{t}} - \sqrt{(M'-c)t}\right) - \exp\left(y\sqrt{M'-c}\right)erfc\left(\frac{y}{2\sqrt{t}} + \sqrt{(M'-c)t}\right)\right]$$

$$B_8 = \frac{\exp\left[-\left(M't + \frac{y^2}{4t}\right)\right]}{\sqrt{\pi t}} + \frac{\exp(bt)\sqrt{M'+b}}{2}\left[\exp\left(-y\sqrt{M'+b}\right)erfc\left(\frac{y}{2\sqrt{t}} - \sqrt{(M'+b)t}\right) - \exp\left(y\sqrt{M'+b}\right)erfc\left(\frac{y}{2\sqrt{t}} + \sqrt{(M'+b)t}\right)\right]$$

$$B_9 = \left[\exp\left(y\sqrt{F - cP_r}\right)erfc\left(\frac{y\sqrt{P_r}}{2\sqrt{t}} + \sqrt{\frac{(F - cP_r)t}{P_r}}\right)\right]\left(\frac{t\exp(-ct)}{2} + \frac{yP_r\exp(-ct)}{4\sqrt{F - cP_r}}\right) + \left[\exp\left(-y\sqrt{F - cP_r}\right)erfc\left(\frac{y\sqrt{P_r}}{2\sqrt{t}} - \sqrt{\frac{(F - cP_r)t}{P_r}}\right)\right]\left(\frac{t\exp(-ct)}{2} - \frac{yP_r\exp(-ct)}{4\sqrt{F - cP_r}}\right)$$

$$B_{10} = \frac{1}{2}\left[\exp\left(-y\sqrt{F}\right)erfc\left(\frac{y\sqrt{P_r}}{2\sqrt{t}} - \sqrt{\frac{Ft}{P_r}}\right) + \exp\left(y\sqrt{F}\right)erfc\left(\frac{y\sqrt{P_r}}{2\sqrt{t}} + \sqrt{\frac{Ft}{P_r}}\right)\right]$$

$$B_{11} = \frac{\exp(-ct)}{2}\left[\exp\left(-y\sqrt{F - cP_r}\right)erfc\left(\frac{y\sqrt{P_r}}{2\sqrt{t}} - \sqrt{\frac{(F - cP_r)t}{P_r}}\right) + \exp\left(y\sqrt{F - cP_r}\right)erfc\left(\frac{y\sqrt{P_r}}{2\sqrt{t}} + \sqrt{\frac{(F - cP_r)t}{P_r}}\right)\right]$$

$$B_{12} = \left[\exp\left(-y\sqrt{bS_c}\right)erfc\left(\frac{y\sqrt{S_c}}{2\sqrt{t}} - \sqrt{bt}\right)\right]\left(\frac{\exp(bt)}{2} + \frac{bt\exp(bt)}{2} - \frac{ybS_c\exp(bt)}{4\sqrt{bS_c}}\right) + \left[\exp\left(y\sqrt{bS_c}\right)erfc\left(\frac{y\sqrt{S_c}}{2\sqrt{t}} + \sqrt{bt}\right)\right]\left(\frac{\exp(bt)}{2} + \frac{bt\exp(bt)}{2} + \frac{ybS_c\exp(bt)}{4\sqrt{bS_c}}\right)$$

$$B_{13} = \frac{\exp(at)}{2}\left[\exp\left(-y\sqrt{a + M'}\right)erfc\left(\frac{y}{2\sqrt{t}} - \sqrt{(a + M')t}\right) + \exp\left(y\sqrt{a + M'}\right)erfc\left(\frac{y}{2\sqrt{t}} + \sqrt{(a + M')t}\right)\right]$$

$$B_{14} = \left[\exp\left(y\sqrt{M'}\right)erfc\left(\frac{y}{2\sqrt{t}} + \sqrt{M't}\right)\right]\left(\frac{t}{2} + \frac{y}{4\sqrt{M'}}\right) + \left[\exp\left(-y\sqrt{M'}\right)erfc\left(\frac{y}{2\sqrt{t}} - \sqrt{M't}\right)\right]\left(\frac{t}{2} - \frac{y}{4\sqrt{M'}}\right)$$

$$B_{15} = \frac{\exp(bt)}{2}\left[\exp\left(-y\sqrt{b + M'}\right)erfc\left(\frac{y}{2\sqrt{t}} - \sqrt{(b + M')t}\right) + \exp\left(y\sqrt{b + M'}\right)erfc\left(\frac{y}{2\sqrt{t}} + \sqrt{(b + M')t}\right)\right]$$

$$B_{16} = \left[\exp\left(y\sqrt{F}\right)erfc\left(\frac{y\sqrt{P_r}}{2\sqrt{t}} + \sqrt{\frac{Ft}{P_r}}\right)\right]\left(\frac{t}{2} + \frac{yP_r}{4\sqrt{F}}\right) + \left[\exp\left(-y\sqrt{F}\right)erfc\left(\frac{y\sqrt{P_r}}{2\sqrt{t}} - \sqrt{\frac{Ft}{P_r}}\right)\right]\left(\frac{t}{2} - \frac{yP_r}{4\sqrt{F}}\right)$$

$$B_{17} = erfc\left(\frac{y\sqrt{S_c}}{2\sqrt{t}}\right)$$

$$B_{18} = \frac{\exp(bt)}{2}\left[\exp\left(-y\sqrt{bS_c}\right)erfc\left(\frac{y\sqrt{S_c}}{2\sqrt{t}} - \sqrt{bt}\right) + \exp\left(y\sqrt{bS_c}\right)erfc\left(\frac{y\sqrt{S_c}}{2\sqrt{t}} + \sqrt{bt}\right)\right]$$

$$M' = M + \frac{1}{K},\ b = -\frac{M'}{S_c - 1},\ c = \frac{F - M'}{P_r - 1},\ d = c\left(F - M'\right)$$

❖ DISCUSSION, RESULTS AND CONCLUSIONS

In order to get the physical insight into the problem, we have plotted velocity profiles for different parameters M (Magnetic parameter), K (permeability parameter), S (visco-elastic parameter), Gm (Mass grashof number), t (time), a (accelerating parameter), F (Heat source parameter) and Sc (Schmidt number) in Figures (1) to (16) for the cases of heating (Gr<0) and cooling (Gr>0) of the plate. The heating and cooling take place by setting up free convection current due to temperature and concentration gradient.

Figures (1) and (2) illustrate the influences of M (Magnetic parameter) on the velocity field in cases of cooling and heating of the plate at t=0.2 respectively. From these figures the velocity is found to decrease with an increase in M for the case of heating of the plate. It is because that the application of transverse magnetic field will result a resistitive type force (Lorentz force) similar to drag force, which tends to resist the fluid flow and thus reducing its velocity. But the reverse effect is found in the case of cooling of the plate. It is also found that in the case of cooling, the velocity increases near the surface of the plate and becomes maximum and then decreases away from the plate. The reverse phenomenon is found in the case of heating of the plate.

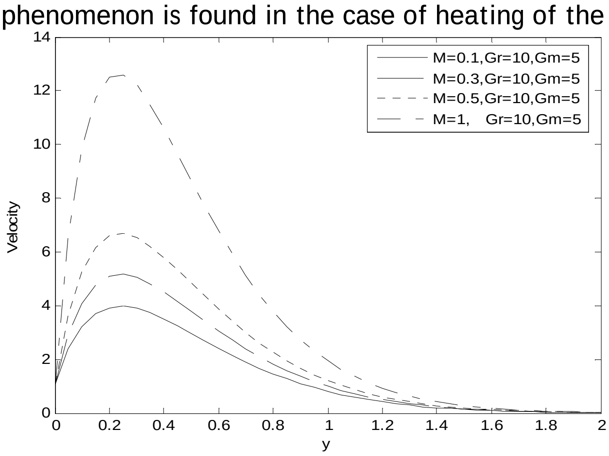

Figure 1. Velocity profiles when Pr=0.1, Sc=0.78, k=0.5, a=0.5, S=0.05, F=4, t=0.2

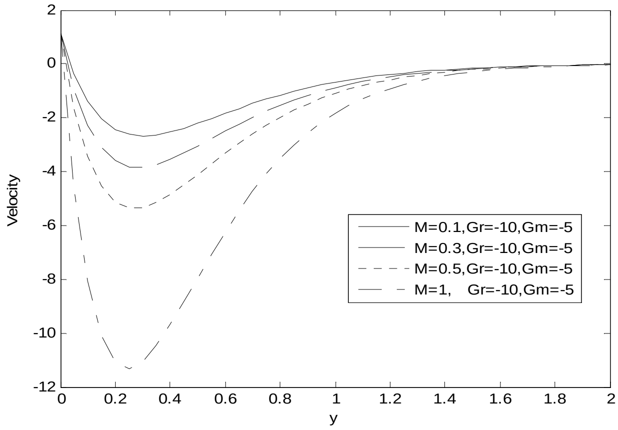

Figure 2. Velocity profiles when Pr=0.1, Sc=0.78, k=0.5, a=0.5, S=0.05, F=4, t=0.2

Figures (3) and (4) represent the velocity profiles due to the variations in K(permeability parameter) in cases of cooling and heating of the plate at t=0.2 respectively. From these figures the velocity is observed to increase with an increase in permeability parameter K for the case of heating of the plate. This is due to the fact that the presence of a porous medium increases the resistance to flow. But the reverse effect is observed in the case of cooling of the plate.

Figures (5) and (6) display the effects of S (visco-elastic parameter) on the velocity field for the cases cooling and heating of the plate at t=0.2 respectively. In the case of cooling of the plate, it is observed that the velocity is less for Newtonian fluid (S is equal to zero) than the Non-Newtonian fluid (S is not equal to zero) and also the velocity increases with an increase in S. But the opposite phenomenon is observed in the case of heating of the plate.

Figures (7) and (8) reveal velocity variations with Gm (mass grashof number) in the cases of cooling and heating of the plate at t=0.2 respectively. From the figures it is observed that the velocity increases with an increase in mass grashof number Gm in the case of cooling of the plate. It is due to the fact increase in the values of mass Grashof number has the tendency to increase the mass buoyancy effect. This gives rise to an increase in the induced flow. The reverse effect is observed in the case of heating of the plate.

Figures (9) and (10) represents the velocity profiles for different values of t (time) in cases of cooling and heating of the plate respectively. From the figures, in the case of cooling of the plate, the velocity is found to increase with an increase in time t. But the reverse effect is observed in the case of heating of the plate.

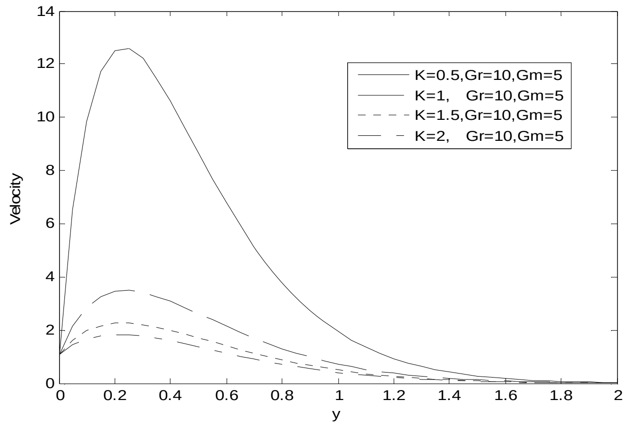

Figure 3. Velocity profiles when Pr=0.1, Sc=0.78, k=0.5, a=0.5, S=0.05, M=1, F=4, t=0.2

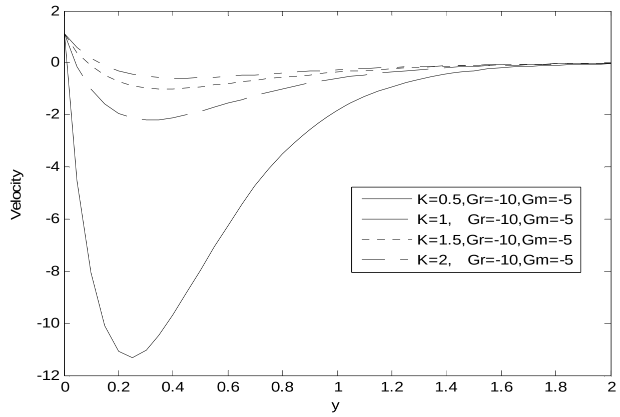

Figure 4. Velocity profiles when Pr=0.1, Sc=0.78, k=0.5, a=0.5, S=0.05, M=1, F=4, t=0.2

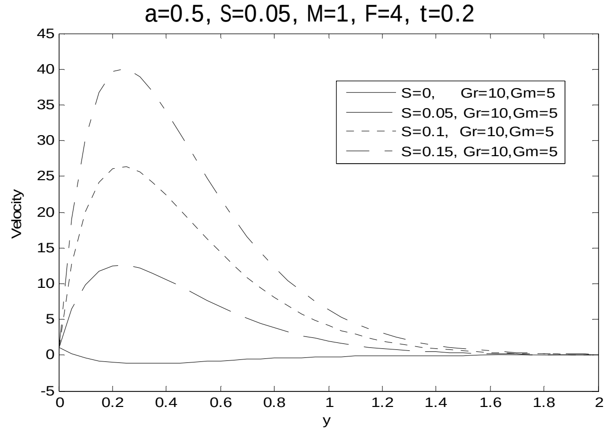

Figure 5. Velocity profiles when Pr=0.1, Sc=0.78, k=0.5, a=0.5, M=1, F=4, t=0.2

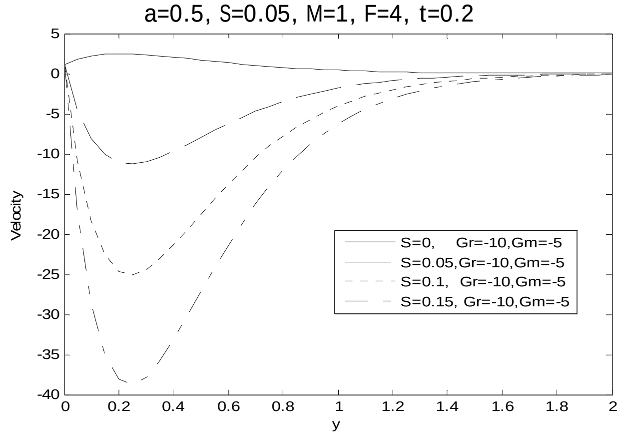

Figure 6. Velocity profiles when Pr=0.1, Sc=0.78, k=0.5, a=0.5, M=1, F=4, t=0.2

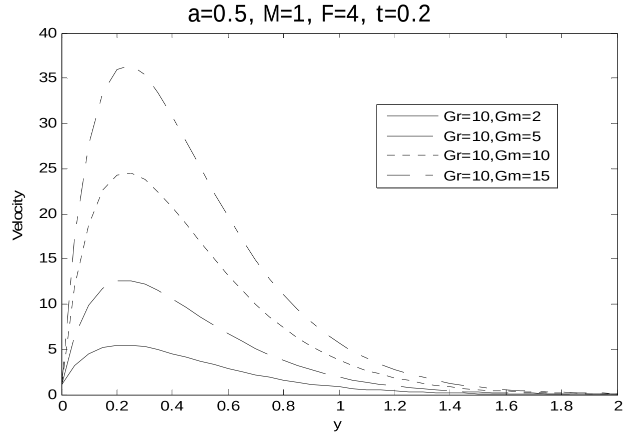

Figure 7. Velocity profiles when Pr=0.1, Sc=0.78, k=0.5, a=0.5, M=1, F=4, t=0.2

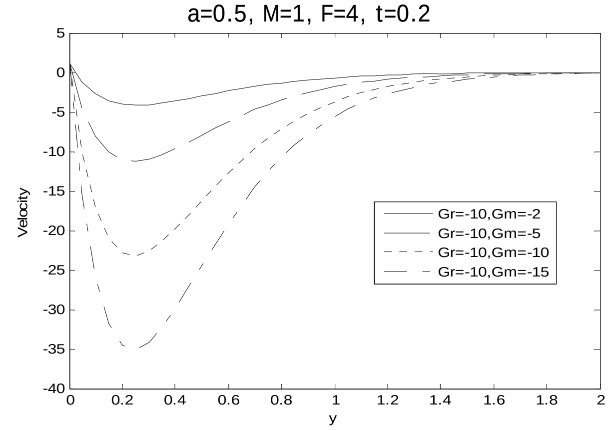

Figure 8. Velocity profiles when Pr=0.1, Sc=0.78, k=0.5, a=0.5, S=0.05, M=1, F=4, t=0.4

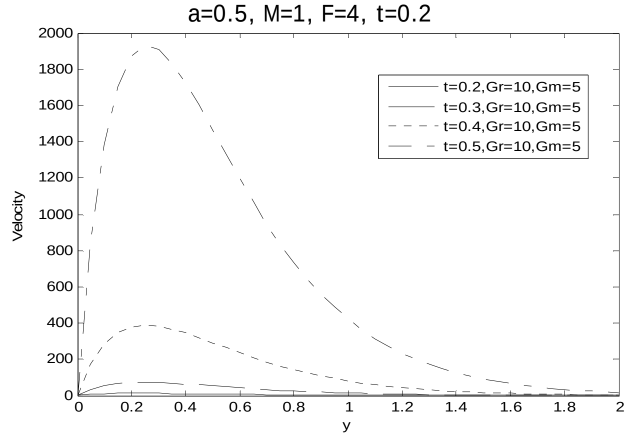

Figure 9. Velocity profiles when Pr=0.1, Sc=0.78, k=0.5, a=0.5, S=0.05, M=1, F=4

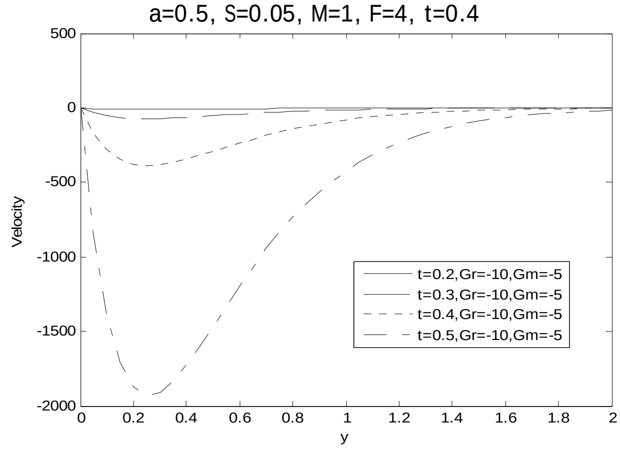

Figure 10. Velocity profiles when Pr=0.1, Sc=0.78, k=0.5, a=0.5, S=0.05, M=1, F=4

Figures (11) and (12) represent the velocity profiles for different values of a (accelerating parameter) in cases of cooling and heating of the plate at t=0.2 respectively. From the figures the velocity is found to increase with an increase in a (accelerating parameter) in cases of both cooling and heating of the plate. It is also found that the fluid velocity due to the impulsive start of the plate (a is equal to zero) is less than due to the exponentially accelerated start (a is not equal to zero) in cases of both cooling and heating of the plate.

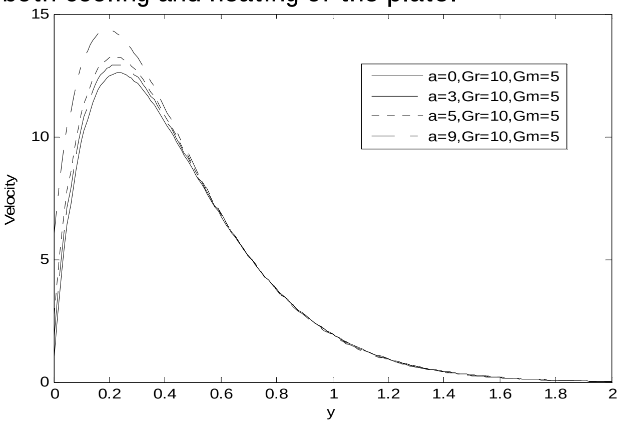

Figure 11. Velocity profiles when Pr=0.1, Sc=0.78, k=0.5, S=0.05, F=4, M=1, t=0.2

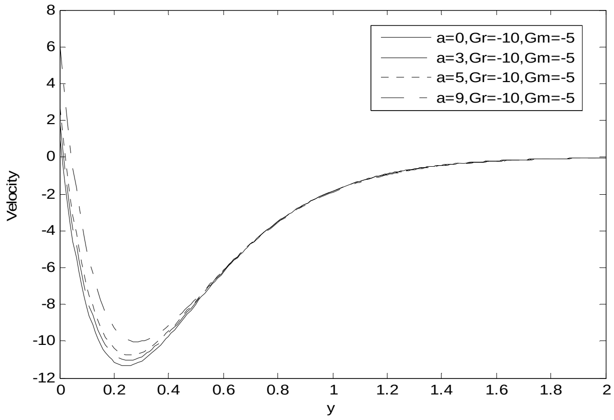

Figure 12. Velocity profiles when Pr=0.1, Sc=0.78, k=0.5, F=4, S=0.05, M=1, t=0.2

To observe the effect of F, the velocity profiles for different F (Heat source parameter) are presented in figures (13) and (14) in cases of cooling and heating of the plate at t=0.2 respectively. It is observed that there is negligible effect of F on the velocity in cases of both cooling and heating of the plate. It is also observed that, in the case of cooling of the plate, the velocity increases near the surface of the plate and becomes maximum and then decreases away from the plate. But the opposite effect is observed in the case of heating of the plate.

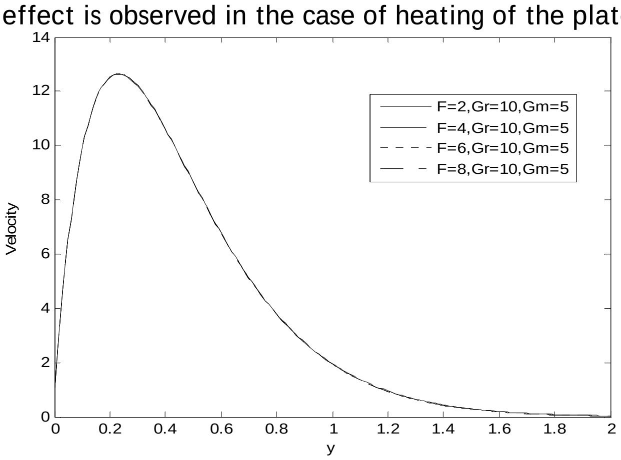

Figure 13. Velocity profiles when Pr=0.1, Sc=0.78, k=0.5, a=0.5, S=0.05, M=1, t=0.2

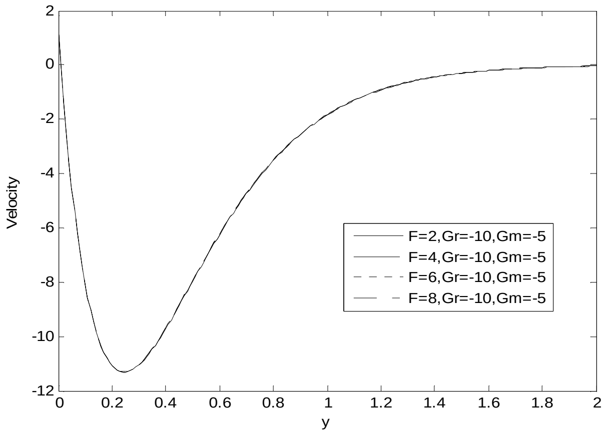

Figure 14. Velocity profiles when Pr=0.1, Sc=0.78, k=0.5, a=0.5, S=0.05, M=1, t=0.2

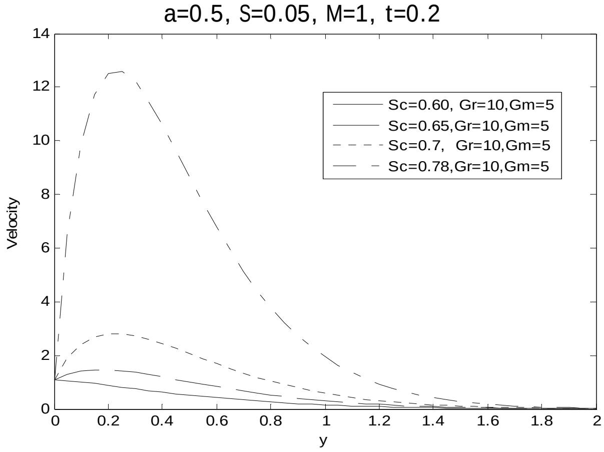

Figure 15. Velocity profiles when Pr=0.1, k=0.5, a=0.5, S=0.05, F=4, M=1, t=0.2

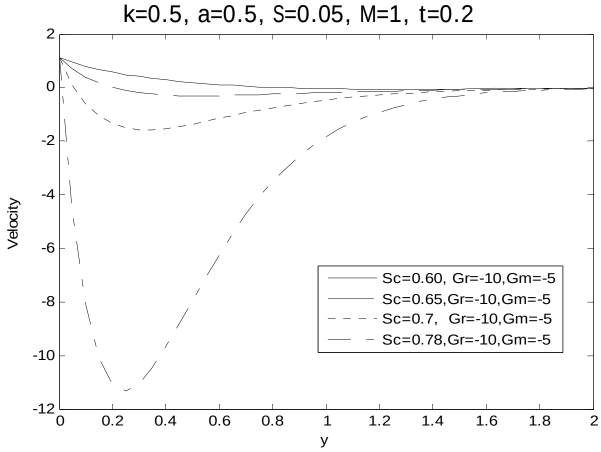

Figure 16. Velocity profiles when Pr=0.1, k=0.5, a=0.5, S=0.05, F=4, M=1, t=0.2

Figures (15) and (16) display the effects of Sc (Schmidt number) on the velocity field for the cases of cooling and heating of the plate at t=0.2 respectively. From the figures, in the case of cooling of the plate, it is found that the velocity increases with an increase in Sc. But the reverse effect is found in the case of heating of the plate.

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❖ APPENDIX - NOMENCLATURE

C'_∞ *Concentration in the fluid far away from the plate*
C'_w *Concentration of the plate*
A *Constant*
y' *Coordinate axis normal to the plate*
C *Dimensionless concentration*
y *Dimensionless coordinate axis normal to the plate*
u *Dimensionless velocity*
B_0 *External magnetic field*
G_m *Mass Grashof number*
P_r *Prandtl number*
S_C *Schmidt number*
C' *Species concentration in the fluid*
C_p *Specific heat at constant pressure*
T'_∞ *Temperature of the fluid far away from the plate*
T' *Temperature of the fluid near the plate*
T'_w *Temperature of the plate*
k *Thermal conductivity of the fluid*
G_r *Thermal Grashof number*
t' *Time*
u' *Velocity of the fluid in the* x' *-direction*
u_0 *Velocity of the plate*
a *Accelerating parameter*
D *Chemical Molecular diffusivity*
g *Acceleration due to gravity*
K *permeability parameter*
M *Magnetic field parameter*
F *Heat Source parameter*
S *Visco-elastic parameter*
t *Dimensionless time*
μ *Coefficient of viscosity*
$erfc$ *Complementary error function*
ρ *Density of the fluid*
θ *Dimensionless temperature*
σ *Electric conductivity*
erfError function
ν *Kinematic viscosity*
α *Thermal diffusivity*
β^* *Volumetric coefficient of expansion with concentration*
β *Volumetric coefficient of thermal expansion*
w *Conditions on the wall*
∞ *Free stream conditions*

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